QUALITY WHEAT
CRC PROJECT REPORT

Prgram 5 : Flour & Dough Components and their Interaction

Project: 5.1.3

Alpha Amylase Workshop

Compiled by: Clare Johnson

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Alpha Amylase Workshop

Wednesday 31 January 2001
QWCRC, North Ryde.

- Executive summary, recommendations, action plan for project

Presentations:
- Implications for weather-damaged wheat (Gerard McMullen, AWB)

Methods of Measurement:
- Falling Number (Michael Southan, BRI)
- RVA (Bronwyn Elliott, Newport Scientific)
- WheatRite (Gill Mearns, QWCRC)
- ReadRite (Dave Edwards, Real Time Engineering)

Issues:
- Storage / Baking quality (Peter Gras, CSIRO)
- Baking quality / Economics (Michael Southan, BRI)
- End user requirements (RVA) (John Dines, GFMB)
- Alpha amylase: active vs inactive (Kevin Gale, CSIRO)
Executive Summary

Implications for weather-damaged wheat  G. McMullen

AWB sets receival standards, including those concerning rain damage to grain, but it is up to the BHCs to implement them, so they are subject to interpretation. Visual inspection for weather damage is subjective and there is a need for an objective test. Falling Number is the only standard to date. It is expensive and requires a skilled operator; consequently the test is not available at all receival sites (mainly at central sites), and operators, trained by BHCs, are often junior and are not always sufficiently skilled. Lack of the test at smaller sites affects the segregations available. The grain is then subject to post-receival testing, which can be poor economics. There is not enough time to test every load. A portable rapid objective test is needed.

Growers want a one-step machine, not multiple possibilities for error, and they want all of industry using the same standard test.

Receival agent concerns include ease of operation, low capital and operating costs, accuracy and ease of audit. Computers set up at all sites would enable collation of quality data. The range of quality tests used includes visual assessment. Falling Number, RVA, and also milling and amylograph. Agents currently audit annually on protein, moisture, screenings and sometimes test weight. A new test should be suited to automated data collection and should also be recognised in export markets.

If grain is dried in storage, a few minutes at 60°C inactivates amylase, but will cause quality changes. (This refers to current moves to harvest grain wetter, then dry in storage to achieve less breakage.) A rain damage test should be able to distinguish active from inactive alpha amylase.

Ed. note: it would be helpful to develop VET-accredited courses, possibly with C-Qentec, and to liaise with NACMA and Australian Standards concerning a new standard method when appropriate.

Methods of Measurement

Falling Number  M. Southan

Rain damage occurs when water stimulates release of gibberelic acid from the scutellum (between the germ and the endosperm), causing synthesis of alpha amylase in the aleuronic layer, and its secretion into the endosperm.

The Falling Number test involves use of a specific grinder to reduce the wheat starch to a certain particle size, mixing with boiling water, and dropping of a precision plunger through the starch gel produced. Alpha amylase activity increases when starch gelatinises at 55-66°C, but the enzyme is inactivated when heat-denatured at 75-80°C. Because it takes a finite time to heat the mix, this means the alpha amylase is active for about 30 seconds during the Falling Number test, mimicking the time available for its activity during the baking process.
The activity and the enzyme’s turnover rate both increase between 60-70°C. Beta
amylase cannot attack starch, but attacks dextrans released by alpha amylase, so if
both enzymes are present, they synergise in starch degradation.

There is a lot of scope for error in the multi-step Falling Number testing process, and
a 5% experimental error level is considered good. However this translates to
plus/minus 15 units for a Falling Number reading of 300, so can have a large
economic impact to the grain producer. This is compounded by issues such as whether
or not the receival point is air-conditioned, and whether it is at sea level (port) or a
higher altitude inland, which affects the boiling point.

Requirements include accurate weighing, distilled water, and precision in shaking
time and number of oscillations. Tubes are often broken, so use of imprecise non-
manufacturer’s tubes is a concern, and incomplete washing of tubes can lead to
contamination of samples.

**RVA B. Elliott**

* A handout, “RVA Market and Technical Review” is appended.
The cost of an RVA instrument is $12,000, similar to that of a Falling Number
instrument, but it has the advantages of ruggedness, portability and ease of use, while
providing an accurate, objective result correlated to Falling Number. The Megazyme
test is commonly used, but the Falling Number instrument is the only one referred to
in the AWB standards. The RVA result is viscosity at 3 minutes, so the test is more
rapid than a Falling Number test. The RVA gives better repeatability than the Falling
Number test, and RVA results are less affected by the conditions in the silo. The RVA
“stirring number test” has not been widely adopted despite endorsement by the
AACC, ICC and RACI. RVA gelatinisation profile has gained wider acceptance.
Marketplace education would be necessary to increase adoption, and subsidies would
assist.

**WheatRite G. Mearns**
The Wheat Rite immunochromatography test produces a result in 5 minutes, but takes
15 minutes to run to completion. Cards must be opened at a set time (5 minutes
recommended) to ensure results are directly comparable when stopping the reaction
before completion. The reader currently reads a 1 mm band on the strip, but doesn’t
scan. Variation across the strip is due to properties of the nitrocellulose, such as pore
size.

Improvements now incorporated in the card and protocol include a wider test strip,
(6mm), which is easier to interpret by eye, results in less positioning error in the
reader, and is compatible with the Binax manufacturing process. A larger sample
volume (100µl) is now added onto a large sample pad which narrows at the top to
focus the sample as it flows from the pad to the strip, picking up most of the gold
conjugate within 5 minutes. This means variation in sample addition is less critical,
and removes the requirement to add buffer reagent.

The system shows good correlation with Falling Number for fresh samples, but results
from stored grain are variable. A coefficient of variation of less than 5% is required
for correlation with Falling Number. This poses a problem for Falling Number
readings of 150, but not 250. In experiments with lot #010151, which was 6mm wide,
larger coefficients of variation were produced, though these were not significantly different and were still within specifications. The calibration set for the old strip was used in these tests. (A totally new test format is also currently under development, since the sale of AMRAD-ICT.)

**ReadRite  D. Edwards**

The different series of WheatRite standard Falling Number cards affect the calibration of the ReadRite reader, and results at 7 minutes differ from those at 5 minutes. There are also large differences between varieties. It is proposed to change the calibration such that, for example, the manufacturer provides standard samples for each batch, and the user enters the colour value specified for the standard with high Falling Number. Use of a PC camera to read the full width of the band would reduce the need for accurate alignment, but introduce problems with edge effects.

**Issues**

**Storage / Baking quality  P. Gras**


Slides demonstrating reduction in flour quality when stored at 37°C over the season (later results indicate cutoff above 20°C) were presented. Although weather damage reduces baking quality, it has little effect on mixing properties. Since alpha amylase activity of the sample decreases over time in storage, can storage counteract the effect of weather damage on baking performance?

Trials were performed on grain samples from around the country (Pinnaroo SA, Turreffeld WA, Narrabri NSW, Wagga Wagga NSW and Yanco NSW). RVA results from these samples had a correlation of 0.965 with Falling Number. The changes occurred slowly in dry samples and rapidly in samples with high storage water activity, characteristic of chemical reaction. Stirring Number increased with storage time, while Loaf Score decreased.

**Conclusions:**

- In any future experiments, need to mix for the optimised time/ number of oscillations for the particular flour.
- Storage will reduce the amount of active alpha amylase in stored grain, but baking properties of weather-damaged grain do not improve with storage, probably because other dough components such as starch or non-starch polysaccharides are also damaged. (Late Maturity Amylase will affect baking quality, but is not abundant.)
- Grain handlers will find that weather-damaged grain passes tests such as Falling Number if stored long enough, but will nonetheless have impaired baking quality.
- Therefore grain must be graded on receival, and appearance of weather staining, shot or sprung grain be taken into account.

The WheatRite/storage result is still to come.
**Baking quality / Economics**  
*M. Southan*

The final structure of a loaf and its rate of staling depend on the gelatinisation quality of the starch. A gel which sets too quickly will reduce oven-spring, while if a gel is too fluid (eg due to starch degradation by alpha amylase), the loaf will collapse and have sticky crumb due to dextrins now present.

High Falling Number can also depend on the gelatinisation properties of the starch. Bread can be made from flour with Falling Number 200, but the formulation must be changed.

ASW, GP and Feed wheat (Port Kembla data) were selected for economic comparison, in order to remove protein levels from consideration. This showed a $12/tonne difference between wheat with Falling Numbers of 300 and 250 respectively. (Note: the price for feed wheat ($134/tonne) is currently inflated.)

**End user requirements (RVA)**  
*J. Dines*

A similar economic comparison was presented (Sydney samples, GST included, slide 3) along with a more detailed analysis (slide 18, bottom p. 9), which showed changes of grade in both directions as a result of misclassification. There were fewest misclassifications using WheatRite. A sliding scale for Falling Number-dependent payment, similar to the scale for protein in the Golden Grain scheme, was suggested, but it was felt there were too many variables.

Minimum Falling Number is stated as a quality requirement in all grain contracts and failure to meet contractual requirements results in monetary claims. Any method employed must satisfy end users, grain marketers, purchasers in the domestic and export markets and grain handling authorities, and must not financially disadvantage growers. It must be accepted internationally or be highly correlated with such a method. AWB states that Bulk Handling Companies may adopt their own procedures, provided the method correlates well with Falling Number. Goodman Fielder's food manufacturing customers have specifications relating to amylograph peak viscosity, but Falling Number is not a good predictor of this (slides 24-25 p. 12-13). The RVA can provide both results and so satisfies all requirements of the millers.

A set of 14 wheat samples covering various grades and varieties on the east coast was analysed by Falling Number, RVA and WheatRite */ReadRite* methods (slides 11-12, p. 6-8) and the methods rated by parameters including cost, time, ease of use etc (slide 16 p.8). Several of the following tables showed GrainCorp's Falling Number calculation from Stirring Numbers using regression analysis (derivation slide 27 p. 14. For discussion: is the slope or intercept of this graph more important?). In the table comparing wheat grades, there were $10/tonne jumps between levels. The chart in slide 19 (p.10) is adjusted back to a common average. The GrainCorp regression comes up well, with no differences.

WheatRite appeared superior on portability, cost and time, and RVA scored higher than Falling Number on reproducibility and calibration. However, number of samples to be analysed is a consideration, and RVA had the highest requirement for analytical skills. The ReadRite reader needs further work to provide valid calibration before industry acceptance. LMA should also be investigated.
Alpha amylase: active vs inactive  K. Gale

Regarding storage of grain, it would be useful to know whether alpha amylase detected was still active, in view of the results presented earlier by Peter Gras. In grain stored at 4°C for 2-3 years, Falling Numbers increased from 150 to 215.

The hypothesis was presented:
- Falling Number and RVA measure amylase activity, which decreases due to inactivation during storage.
- WheatRite measures amylase antigen, irrespective of activity, and therefore may represent a superior indicator of baking performance in stored grain.

The second point should be valid, as long as inactivation of amylase does not cause conformational changes which prevent its being recognised by the antibody. WheatRite measurement would take into account past degradation.

A storage experiment with Janz, Hartog and Sunstate, in three Falling Number groupings, was designed to test this hypothesis. At 4°C/55% relative humidity, one would expect minimal changes; at 30°C/55%RH moderate changes, and at 37°C (a realistic temperature)/55%RH, large changes. (55%RH is the equilibrium humidity of saturated glucose and remains constant over a wide range of temperatures).

700g samples are available to conduct this experiment. A Falling Number test requires 300g for a representative sample size. The group recommended use of at least 100g for this experiment. Samples are to be pre-divided (this makes a big difference). RVA and mixograph measurements should be added to protocol, as well as Falling Number measurement.

This experiment will be conducted over the first half of 2001.

Record of Discussion/Action Plan
- RVA has not been done on stored wheats.
- log [alpha amylase] is directly proportional to Falling Number.
- Can we formulate recommendations to store grain long enough to recover Falling Number? P. Gras has figures for GP→ASW. However, consider baking quality.
- The test finally adopted by industry must take less than 3 minutes.
- Heat disinfection methods are very close to areas where quality is damaged.
- When drying grain, these conditions must also be avoided.
- In noodles, weather damage causes green noodle sheet.
- Blending experiments with a range of damaged wheat would be informative.
- Storage experiments (K. Gale, above) should be done first, then look further.
- P. Gras recommended Kevin mixes to optimum time per sample (peak dough development) rather than a standard time, in order to obtain clear results for the parameter in question. All sub-samples should then be mixed to this criterion.
- Kevin should also ensure the operator doesn’t turn the instrument off prematurely, as the graph peaks, dips, then rises again.
- Correlate with Stirring Number?
• Kevin should set up storage of rain-damaged grain for 6 months immediately, to be ready for future work.

• ReadRite: Dave Edwards should be using rankings (non-parametric statistics) for calibration at high Falling Number. Three points are better than two. We need to differentiate FN 300 and 350 and a lower point in mid-range. The result is achieved via a lookup table, and is not a function transforming a curve to a line.
Effect of storage and thermal treatment on quality of rain-damaged wheat

P.W. Gras*, M.L. Bason* and J.D. Tomlinson†

Abstract

Quality of rain-damaged grain as measured by Falling Number or Rapid Visco-Analyzer (Stirring Number) increases during storage. In contrast, other measures of grain quality, such as mixing properties, decline during storage. Elevated temperature treatments of sound and rain-damaged grain show that the deactivation of alpha-amylase is slower than the degradation in quality as measured by mixing tests. The kinetics of the changes in alpha-amylase activity and grain quality as a function of storage humidity and temperature show that, despite a progressive increase in Falling Number/Stirring Number, grain quality as measured by loaf volume progressively decreases. It is concluded that, for baking applications, remediation of rain damage by manipulation of storage conditions is impractical.

Introduction

Rain damage is a serious, if intermittent problem in Australian wheat. In some years, a significant proportion of grain harvested has some degree of rain damage, which renders it less suitable for the production of pan bread, noodles and the production of starch and gluten.

The damage is a consequence of the initiation of the germination process before harvest. Enzymes required for germination are produced initially in the embryo, scutellum and aleurone cells and released into the endosperm. Alpha-amylase and protease both have significant effects. The common salt used in the baking formula inhibits further proteolysis during the baking process. The effects of cereal alpha-amylase are not fully realized until the baking step of the baking process, where it rapidly hydrolyses gelatinised starch. Elevated levels of alpha-amylase result in loaves with reduced volume, poor colour and poor crumb structure.

The extent of rain damage is usually measured with the Falling Number™ test and/or the Stirring Number test, determined with the Rapid Visco-Analyzer (RVA). Both of these instruments measure the effects of alpha-amylase on the viscosity of a starch paste. Both of these instruments effectively measure the amount of alpha-amylase (Hocking et al. 1993).

Long-term storage of sound wheat is associated with gradual decrease in baking performance. This decrease is presumably related to slow changes in the proteins of the wheat during storage, although whether this due cross-linking, oxidation or degradation is not known.

Falling Number (and Stirring Number) of stored grain are known to increase on long storage (H.J. Banks, pers. comm.). This implies that alpha-amylase can be degraded during storage. Presumably, this degradation is chemical process, and the rate of this process can be described by a form of Arrhenius equation, as described for the yellowing of milled rice (Gras et al. 1989; Bason et al., these proceedings).

The use of a brief steam treatment to inactivate enzymes produced as a result of rain damage has been patented (Hutchinson 1967). However, such treatment would be expensive, and has not been widely adopted. By extending the treatment time, the treatment temperature could be reduced and the inactivation carried out during normal, or near-normal storage conditions. If the rate of degradation of alpha-amylase is greater than the underlying deterioration in grain quality, storage may provide a method for the remediation of rain damage.

This paper describes a mathematical model of the rate of change of Stirring Number (and thus for change in alpha-amylase activity) as a function of storage conditions. The change in apparent rain damage resulting from storage has been related to changes in the baking quality of the stored grain.

Experimental

Samples of grain of three wheat varieties, each grown at five locations were selected from the Interstate Wheat Variety Trials of 1992–93. The selection was made to provide a wide range of initial rain-damage in each of three cultivars (Table 1).

For Stirring Number tests, subsamples of each sample were stored in air at each of seven combinations of storage temperature and water activity. Selected regimes were 55°C (water activities of 0.4, 0.6 and 0.8), 35°C (water activities of 0.4, 0.6 and 0.8) and 23°C (water activity 0.6).

Storage experiments were conducted in glass jars continuously purged with air at the same water activity as the stored grain samples and maintained at the desired temperature (±0.5°C). Grain samples were adjusted to the moisture levels appropriate for the desired temperature/water activity before.

Table 1. Falling Numbers of samples used in the study.

<table>
<thead>
<tr>
<th>Growth Site</th>
<th>Cultivar</th>
<th>Halberd</th>
<th>Hartog</th>
<th>WW879</th>
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<tr>
<td>Pinnaro</td>
<td></td>
<td>471</td>
<td>481</td>
<td>474</td>
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<td>Turreifeld</td>
<td></td>
<td>385</td>
<td>386</td>
<td>390</td>
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<td>Narrabri</td>
<td></td>
<td>290</td>
<td>134</td>
<td>234</td>
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<td>Wagga Wagga</td>
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<td>70</td>
<td>62</td>
<td>136</td>
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<tr>
<td>Yanco</td>
<td></td>
<td>226</td>
<td>138</td>
<td>271</td>
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</tbody>
</table>

* Grain Quality Research Laboratory, CSIRO Division of Plant Industry, R.O. Box 7, North Ryde, NSW 2113, Australia
† Bread Research Institute of Australia Inc., P.O. Box 7, North Ryde, NSW 2113 Australia.
Implications for weather-damaged wheat

Gerard McMullen AWB
Amylase Workshop
January 2001
Implications of Weather Damaged Wheat
For AWB Limited
Gerard McMullen

Current Receival Standards (visual)
- Subjective, therefor “not accurate”
- Controversial, leads to stress
- Open to grower abuse
- Cause significant mass-classification
- Unable to determine extent of problem
- Must be supported by objective testing
- Is very slow

Current Receival Standards (non-visual)
- Only one objective test for field use
- Unable to equip all sites
- Requires complex backup systems
- Requires extensive off site testing in lab to determine real extent of problem
- Not timely as it runs behind receivals
- Issue with artificial drying, mild weather & nonweather damaged grain

Grower Concerns
- Must be timely
- Must be load by load or paddock testing
- Must be accurate & seen to be “high tech”
- Available at all sites
- Provide a simple precise answer
- Used by all industry

Receival Agent Concerns
- Easy to operate, quick
- Accurate & repeatable
- Cheap capital & operational costs
- Meet equipment strategic directions
- Robust unit and test method
- Readily auditable & adjustable
- Fully automated
- Consistent between receival agents

Market Use of Technology for Grain Assessment
- Visual &/or FN at site by Receival Agents
- Visual, FN, RVA on site grade basis
- Based upon RVA, extend testing to milling and amylograph
- RVA bin selection at port
Marketer Concerns

- Objective test
- Accurate & repeatable
- Correlate with existing assessment methods
- Available for use at all sites & by all industry
- Accurate assessment guide suitable for classification purposes
- Reflect level of weather damage

Marketer Concerns (cont)

- Recognised by customers, industry & o/sea
- Proven track record under trials
- Accepted by testing authorities, auditable
- Capable of incorporating additional testing methodologies
- Recognise effects of drying
- Be available soon
Methods of Measurement:

Falling Number

Michael Southan    BRI
**Falling Number**

Michael Southan

BRI Australia

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**Falling Number Test**

- Falling Number test described by Hagberg in 1960
- Method based on rapid gelatinisation of a flour suspension and subsequent degradation of the starch by \( \alpha \)-amylase under conditions similar to baking
Falling Number Test

- Germination of the wheat grain involves the imbibition of water when gibberellic acid is produced in the scutellum and translocated to the aleurone layer
- Gibberellic acid stimulates \( \alpha \)-amylase synthesis in the aleurone layer
- \( \alpha \)-amylase secreted into endosperm
Lashez Number Determination

- Rain Damage
- [only - amylase]
- 7g/25 ml
- (5 g/25 ml flour)
- End Product Quality
Falling Number Test

- Values depend on particle size (grinding technique)
- Shaking technique of slurry critical to providing repeatable results
- Variations occur between different instruments and different operators

Falling Number Test

- α-amylase activity is accelerated when the starch gelatinises at 55-65°C
- α-amylase inactivated when heat denatured at 75-80°C
- α-amylase active for ~30 sec during the Falling Number test
*α*-amylase degrades starch to water soluble dextrins and finally to maltose and glucose

*β*-amylase also hydrolyses parts of the dextrins released by *α*-amylase to maltose
Methods of Measurement:

RVA

Bronwyn Elliott, Newport Scientific
**RVA Market and Technical Review**

Bronwyn Elliott
Newport Scientific Pty Ltd

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**Market Review**
- Market Needs
- Market Segmentation
- Market Motivations
- Technology Analysis
- Development to Meet a Market Need
- RVA Stirring Number Field Results
- International Acceptance
- Conclusion

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**Market Needs**
- α-amylase testing
  - Wheat
  - Barley
  - Rye
- other cereal enzymes

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**Market Segmentation**
- grain growers
- grain receival facilities
- grain exporters and traders
- grain processors
- grain breeders and researchers

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**Market Motivations**
- field test to minimise downgrading
- rapid test to prevent silo downgrading
- accepted & correlated test for pricing
- market advantage and response to change

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**Technology Analysis**
- Visual: subjective
- FN: capital cost, repeatability
- Colourimetric: high laboratory skills
- Antibody: low accuracy
- RVA 3-minute. FN entrenched
- Amylograph: slow, expensive
- RVA cooking/cooling: high skills, expensive
RVA Development to Meet a Market Need

- Accurate
- Objective
- Simple
- Inexpensive
- Correlated to FN
- 3 minutes or less
- Rugged
- Portable
- Easy to use
- Operate without running water

Field Results - 1986
- Australian Wheat Board: "reliable, with repeatability acceptable for utilization in the field."

Field Results - 1995

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<th>Comparison of</th>
<th>Intercept</th>
<th>Slope</th>
<th>r²</th>
<th>RMS</th>
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<td>SW PN, Lab PN</td>
<td>29.5</td>
<td>0.861</td>
<td>0.977</td>
<td>28.8K</td>
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<tr>
<td>SLP PN, Lab PN</td>
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<td>0.860</td>
<td>0.981</td>
<td>38.6RV</td>
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<td>GLN PN, Lab PN</td>
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<td>0.825</td>
<td>0.984</td>
<td>17.2RV</td>
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<td>LAR PN, Lab PN</td>
<td>11.5</td>
<td>0.921</td>
<td>0.954</td>
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<td>Comparison of</td>
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<td>Slope</td>
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<td>RMS</td>
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<td>SW PN, Lab PN</td>
<td>13.2</td>
<td>0.566</td>
<td>0.900</td>
<td>39.5~κK</td>
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<td>SLP PN, Lab PN</td>
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<td>0.919</td>
<td>11.0RV</td>
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<td>0.909</td>
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<td>0.296</td>
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Field Results - 2000

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<td>Australian wheat 1995</td>
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<td>US Hard Red Winter 1995</td>
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<td>US Durum Winter 1995</td>
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<td>-0.30</td>
<td>0.476</td>
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International Acceptance
- RVA Stirring Number Test
  - AACC
  - ICC
  - RACI
- RVA gelatinisation profile
  - RVA-StarchMaster
  - RVA-Super3
  - RVA-4

Conclusion
- FN entrenched worldwide
- New technologies already available
- Education to open the market
- Assistance to stimulate uptake
Methods of Measurement:

WheatRite

Gill Mearns QWCRC
WheatRite Test
- Unidirectional lateral flow test
- Patented folding card design

Issues for the WheatRite Test
- Binax uses different manufacturing processes

Current test format issues
- Manufacturing - component positioning
- Correct sample addition is important

Effects of sample positioning
Options for WheatRite

- Totally new test format
  (Different manufacturer)

Requirements for an improved test

- Less operating steps
- Compatible with the ReadRite

Improved test format

- 100µl Sample
- Test Strip
- No Wash Pad

Sample Addition

- Gold conjugated antibodies
- Antigen from sample

Sample re-hydrates gold

- Gold conjugate
- Antigen from sample
- **Test Strip**
  - Test Line
  - Measurement
  - strip-a-compatible

- **Close Card**
  - Sample pad contents
  - base of test strip
  - Absorbent Pad contacts
  - top of test strip
  - Reagents flow along
  - test strip

- **Positive Sample**
  - This produces a
  - pink line in the test line area.

- **Results**
  - 

- **Results Interpretation**

- **Achievements of improved format**
  - 6mm test strip:
  - easier to visualise by eye
  - easier to position in the reader
  - compatible with Binex manufacturing
Further Work

- Continue development of totally new test format

Continuing challenges for WheelRite

- Introduction of the ReadRite

ReadRite Reader

- Test to test with the same sample

- Manufacturing "Lot to Lot" variation.

Repeatability Experiments

| 300  | 10   | 308.9 | 8.72  | 1.87  | 298-317 | 19    |
| 300  | 10*  | 314.3 | 5.68  | 1.74  | 300-323 | 17    |

Repeatability Experiments

| 300   | 10   | 308.9 | 1.24  | 7.94  | 7.56    |
| 300*  | 0.08 | 0.08  | 0.08  | 0.08  | 0.08    |

CV %
Characteristics of ICT's:

- Creates patches of light and dark areas across the test line.

Test Line Representation:

Summary:

- Remain challenges to using the ReadRite.
Methods of Measurement:

ReadRite

Dave Edwards Real Time Engineering
READ-RITE MEASUREMENT PROCEDURE

1. RAW OPTIC SCAN

2. BASELINE CORRECTION

3. PEAK AREA CALCULATIONS
   Find Peaks and Evaluate:
   Reference Area
   Sample Area

4. RATIO = \( \frac{\text{SAMPLE}}{\text{REF}} \)
   RANGE OF RATIO 0 to 1

5. LOOKUP "RAW" F.N.

6. APPLY CALIBRATION OFFSET
CALIBRATION

Present Calibration Procedure:

"Place 150 Card"  Reads Card. Generates "O 150" Offset
"Place 300 Card"  Reads Card. Generates "O 300" Offset
Generates Offset Table for entire range of Ratios (0 to 1.4)

Problems:

1. User must have 150 and 300 standards. Other F.No. standards cannot be used.
2. Large offsets cause large distortions in resultant calibration curve.
3. Different calibrations result in different Cut-Off points (where Ratio=0).

Proposed New Calibration:

"Place Low F.No. Card "  Reads Card
"Enter the Card F.No.   xxx "  User Enters F.No. value
Calculate offset for that F.No.

"Enter the Cut-Off  F.No. for this batch of cards-
(The F.No. at which No Sample Colour Appears)  xxx "

User enters published Cut-Off point, as supplied by card maker.
Calculate offset for Cut-Off point.
Calculate offset table for entire range of Ratios (0-1.4)

LIMITATIONS/ IMPROVEMENTS

1. Alignment of Card in Drawer.
   Because of the poor tolerance of strip placement on the card during manufacture, the user must align the card centrally in the drawer.

2. Colour Non-Uniformity of Cards.
   The Reader looks at a 1.2mm wide strip down the center of the card.
   Because the coloured bands are not of completely uniform colour, different sideways positions in the drawer produce different F.No. results (differences of 15-20 units).

3. Possibility of using a PC camera as the basis of the optics.
   This would eliminate the need for the user to accurately align the card.
   The processor could find the strip and evaluate the full width of the coloured bands.
   -but edge effects degrade the measurements.
   Resolution Along the strip is poorer (600 pixels vs. 2048).
   Possible cost savings.
Fig. 2a
Typical Calibration
(Diagram)

F.N.

350
300
250
200
150
100
0

R = Test Area
PC Area

O300
O300

O150
O150

CALIBRATED CURVE

RAW, 'IDEAL' CURVE

Fig. 2b
Poor Calibration

F.N.

350
300
250
200
150
100
0

R = Test Area
PC Area

O150 = 0

0.5
0
1
Issues:

Storage / Baking quality

Peter Gras CSIRO
Storage of weather-damaged wheat.

Peter W. Gras

CRC Seminar 31/01/2001

- Change in quality during storage of sound grain is mediated through change in the proteins of the grain.
- Changes observed affect mixing behaviour, baking properties, molecular weight of proteins.
Dough Development Time vs Storage Time 1996

- 4C, 21%
- 4C, 21%
- 35C, 1%
- 90C, 4.8%
- 90C, 21%

Extensograph R-Max vs Storage Time 1996

- 4C, 21%
- 4C, 21%
- 35C, 1%
- 90C, 4.8%
- 90C, 21%
• Change in protein resulting from storage appears to be oxidative polymerisation.
- It has long been known that the Falling number of stored grain increases during storage.

- In one well documented trial, the Falling Number of grain stored for 20 years increased from 300 to 1600 seconds.

- Since alpha amylase is a protein, it is reasonable to expect changes in alpha-amylase activity resulting from changes induced during grain storage.
• Baking properties of flour from weather damaged grain are greatly degraded compared to sound grain. Surprisingly, the mixing properties of flour from weather damaged grain are not much different from those of flour from sound grain.

• The major reduction in baking quality which is characteristic of weather damaged grain seems to be associated with the high level of alpha-amylase (and damaged starch) present in the grain.
• The question which must be addressed is "Can the reduction of Falling Number of weather damaged grain induced by storage also improve baking performance of that grain?"

• Two temperatures - 35C and 55C
• Three storage humidities (water activities)
  - 40% (8.5% moisture), 60% (12% moisture) and 80% (15.5% moisture)
• Three wheat lines from each of five sites, representing a range of weather damage.
Table 1. Falling Numbers of samples used in the study.

<table>
<thead>
<tr>
<th>Growth Site</th>
<th>Hallsdi</th>
<th>Hartog</th>
<th>WW679</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennaroe</td>
<td>471</td>
<td>481</td>
<td>474</td>
</tr>
<tr>
<td>Turrerfield</td>
<td>385</td>
<td>386</td>
<td>390</td>
</tr>
<tr>
<td>Narrabri</td>
<td>290</td>
<td>134</td>
<td>234</td>
</tr>
<tr>
<td>Wagga Wagga</td>
<td>78</td>
<td>62</td>
<td>136</td>
</tr>
<tr>
<td>Yanco</td>
<td>226</td>
<td>130</td>
<td>271</td>
</tr>
</tbody>
</table>

Fig. 1. Change in Stirring Number for cultivar Hartog from Pennaroe stored at 35°C and three water activities.
Fig. 2: Change in stirring number for samples of WWP from Wogla Village stored at 25°C and 35°C in open air and in closed containers.

Fig. 3: Relation between storage number and storage time, and between Leaf Size and storage time for un-damaged grains stored at 25°C with open air and in closed containers.
- Storage will reduce the amount of active alpha-amylase in the stored grain.
- Baking properties of weather-damaged grain do NOT improve with storage. Presumably this is because of associated damage to other dough components such as starch or non-starch polysaccharides.

- This leaves grain handlers with a particular difficulty - weather-damaged grain can pass an alpha-amylase based test (ie Falling Number) if stored for long enough.
- Grain must still be graded on appearance. Weather staining, evidence of shot and sprung grain must remain an over-riding quality consideration.
Issues:

Baking quality / Economics

Michael Southan BRI
Baking Options

Michael Southan
FPi Australia

Function of Starch during Baking

- Important for water absorption
- Sets the dough structure to form bread crumb

bread crumb is a starch gel
Amylase function is to hydrolyse starch to:

1. Sustain yeast/fermentation
2. Create dough fluidity

Bread can be made from flour with FN as low as 200 sec but changes to the formulation are required.
Baking Quality

- Optimum maltose content is 1.5% for 9% protein flour to 2.5% for 13% protein flour.
- The final structure of the loaf and its rate of staling depends on the gelatinisation quality of the starch.
- If a gel is set quickly → reduced oven spring. If a gel is too fluid → loaf collapse and sticky crumb.

Sprouting → Processing Problems
\[ \alpha \text{-amylase} \]

\[ \alpha \text{-amylase cleaves starch molecules randomly resulting in reduced viscosity of starch solutions and produce small amounts of fermentable sugars} \]

Together \[ \alpha \text{-amylase} \text{ and } \beta \text{-amylase} \] convert a greater amount of starch to fermentable sugar than either alone (malt)

\[ \text{Sprouting} \rightarrow \text{Sticky Dough} \]
Baking Quality

- Flour with a low FN will generally have low water absorption - reduced product and profit
- Excessive $\alpha$-amylase activity results in slicing problems due to the stickiness of the bread crumb caused by excessive amounts of dextrins formed during baking
Effect of FN on PERS
Issues:

End user requirements (RVA)

John Dines GFMB
WEATHER DAMAGE
ENDUSER
REQUIREMENTS

The method used for the determination of Weather Damage must be acceptable for use as a standard method by

Growers (and Grower Organisations)
Grain Handling Authorities
Grain Marketeers
Grain Purchasers both in the Domestic and International market place
Growers (and Grower Organisations)

Growers suffer heavy financial penalties due to Weather Damage and therefore must have confidence in the reliability (accuracy and reproducability) of any testing regime which can have a significant effect on their income.

- ASW $225.50
- AGP $203.50
- FEED $170.50

---

Grain Handling Authorities

Method employed Must satisfy the requirements of:

End Users and Grain Marketeers
and not financially disadvantage growers
Grain Marketeers

Require a method that is excepted Internationally or is highly correlated with an International method.

Both domestic and International Grain contracts include Minimum Falling Number values as a quality requirement.

Grain Purchasers both in the Domestic and International market place

International and Domestic customers test receipted grain against minimum Falling number specifications.

Delivery of non-conforming GRAIN can result in large Monetary claims against the supplier and their failure to meet contractual requirements.
Wheat Receival Standards AWB Ltd (page 4)

"AWB's preferred method of assessment for sprouted grain in a delivery is by the use of an objective test such as the Falling Number... "

Bulk handling Companies or other receival agents may adopt their own procedures, provided that method correlates well with Falling Number....."
RVA (Rapid Visco-Analyser)

Wheat Rite (Read Rite)
COMPARISON OF AVAILABLE METHODS DEVELOPED FOR THE DETERMINATION of WEATHER DAMAGE

A small sample set of 14 wheat samples, covering various grades and varieties grown on the east coast, were tested using the three methods described previously.

Location 1 was chosen as the Control Sample Set, results from these Controls were used as the basis for evaluating data obtained using other equipment or methods.

<table>
<thead>
<tr>
<th>Falling Number (Control)</th>
<th>RVA</th>
<th>Average</th>
<th>GF 1</th>
<th>GF 2</th>
<th>Average</th>
<th>GC 1</th>
<th>GC 2</th>
<th>Average</th>
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<td>366</td>
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<td>431</td>
<td>431</td>
<td>431</td>
<td>449</td>
<td>454</td>
<td>452</td>
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<td>372</td>
<td>377</td>
<td>375</td>
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<td>248</td>
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<td>455</td>
<td>446</td>
<td>435</td>
<td>425</td>
<td>430</td>
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<td>425</td>
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<td>460</td>
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<td>340</td>
<td>350</td>
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<td>337</td>
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<td>422</td>
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<td>400</td>
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<td>365</td>
<td>313</td>
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<td>116</td>
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### RATING of methods BASED on EASE of USE, COST, etc.

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<th></th>
<th>Falling Number</th>
<th>RVA</th>
<th>Read Rate</th>
<th>Wheat Rite</th>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>Water Supply</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<td>Wash up Required</td>
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<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Waste Water Requirements</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Analytical Balance</td>
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<td>N</td>
<td>N</td>
<td>N</td>
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<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Durability</td>
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<td>N</td>
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<tr>
<td>Reproducability (same equipment)</td>
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<td>Good</td>
<td>?</td>
<td>Good</td>
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<tr>
<td>Reproducability (other equipment)</td>
<td>Variable</td>
<td>Good</td>
<td>?</td>
<td>Good</td>
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<td>International Standard</td>
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<td>Y</td>
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<td>Altitude Effect</td>
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<tr>
<td>Time/Test</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
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<tr>
<td>Cost/Test</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
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<td>Equipment Cost</td>
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<td>High</td>
<td>Low</td>
<td>Nil</td>
</tr>
<tr>
<td>Equipment Service (Cost)</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Nil</td>
</tr>
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</table>
GRAIN RECEIVAL STANDARDS BASED ON FALLING NUMBER VALUES.

Falling Number Classification

> 350  APH
> 300  H2
250 - 300  AUH2
150 - 250  AGP
< 150  FEED

EFFECT of RESULTS on GROWER/GRAIN HANDLER RETURNS

<table>
<thead>
<tr>
<th>ID</th>
<th>Location 1</th>
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<th>Wheat Risk</th>
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<th>GP Risk</th>
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<td>X</td>
<td>290</td>
<td>330</td>
<td>X</td>
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<td>440</td>
<td>380</td>
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<td>187</td>
<td>X</td>
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<td>365</td>
<td>395</td>
<td>366</td>
<td>311</td>
<td>0</td>
</tr>
</tbody>
</table>

| Standard Deviation | 80 | 71 | 2 | 116 | 0 | 66 | 3 | 116 |

X - Values re-PLACE the Grain in a LOWER Category (financial loss to grower)

• Values re-PLACE the Grain in a Higher Category (financial gain to grower) but could compromise grain “slack” in the market place (financial loss to Grain Handler/Marketeer)

*If = Goodman Fielder*
### EFFECT of RESULTS on GROWER/GRAIN HANDLER RETURNS

<table>
<thead>
<tr>
<th>ID</th>
<th>Location 1</th>
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<th>GrainCorp Regression</th>
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<td>530</td>
<td>486</td>
<td>439</td>
<td>475</td>
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</tbody>
</table>

Average: 365
Standard Deviation: 16.5

---

### EQUIPMENT SUMMARY

It is difficult to analyse and compare results from the various methods reviewed therefore I have based my assessment on a number of criteria as follows:

- **Key**
  - * = misclassification (depending on location)
  - X = misclassification (as above), reading not reproduced
  - # = goods
EQUIPMENT SUMMARY

Cost:

*Wheat Rite Kit*, for a small number of samples

*Read Write READER*, for a moderate number of samples

*RVA*, for a large number of samples with rapid throughput

*Falling Number*, for a large number of samples

---

EQUIPMENT SUMMARY

Ease OF use:

*Wheat Rite Kit*, little skill required

*Read Write Reader*, calibration requirements

*Falling Number*, need to be aware of the factors which can influence the end result eg equipment vibration.

*RVA*, need for some analytical skills.
EQUIPMENT SUMMARY

Accuracy:

Wheat Rite Kit, good results, particularly suitable for on farm use.

Read Write Reader, need further work before being accepted for use within the industry e.g. calibration.

Falling Number, variation in results between instruments.

RVA, good correlation within and between instruments ability to calibrate), good correlation with falling number method.

Relationship between AMYLOGRAPH and FALLING NUMBER

The majority of FOOD manufacturers do not specify falling number as part of their ingredient specifications. They tend as an industry group to specify Amylograph peak viscosity. Unfortunately Falling Number is not a good predictor of Amylograph Peak Viscosity.
Relationship between AMYLOGRAPH and FALLING NUMBER

Therefore there is a requirement for the flour manufacturer to monitor both falling number and Amylograph peak viscosity in practice it has been found that the RVA can provide both results by incorporating specific testing profiles for each quality parameters.

Falling Number (Stirring Number) - 3min test at 94 deg C
Amylograph Profile - 20 minute test using temperature ramping from 50 deg C to 92 deg C.

Flour Millers can use the RVA to satisfy all their test requirements for Alpha Amylase on incoming grain

QUESTIONS PLEASE!
### Stirring Number to Falling Number Converter

19/07/2000 MB  

Use this sheet for creating conversion tables from SN (or End Visc in cP) to FNE.  

Note - this spreadsheet does not calculate the conversion equation.  

The equation must be in the form: FNE = a + b*SN  

where a and b are coefficients  

where SN is final viscosity in RVU (=cP/12)

<table>
<thead>
<tr>
<th>Conversion details</th>
<th>FN = 61.1800 + 2.67698 SN (RVU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of grain:</td>
<td>wheat</td>
</tr>
<tr>
<td>Form (e.g., flour):</td>
<td>wholemeal</td>
</tr>
<tr>
<td>Location:</td>
<td>Aus</td>
</tr>
<tr>
<td>Year:</td>
<td>1999</td>
</tr>
<tr>
<td>Source of samples:</td>
<td>Graincorp &amp; SARDI</td>
</tr>
<tr>
<td>Source of data:</td>
<td>Jodi McLean (FN data &amp; samples)</td>
</tr>
</tbody>
</table>

Enter Intercept a: 61.18  

Enter slope b: 2.677
Issues:

Alpha amylase: active vs inactive

Kevin Gale CSIRO
**Alpha Amylase: Active Versus Inactive Enzyme**

Kevyn Gale

**Wheatrite as an Indicator of Falling Number**

Our observation: Wheat rita and FN test results diverge for stored weather-damaged grain

**Wheatrite as an Indicator of Weather Damage in Stored Grain**

The hypothesis

FN and RVA measure amylase activity which decreases due to inactivation during storage. Wheatrite measures amylase antigen, irrespective of activity and therefore may represent a superior indicator of baking performance of stored grain.

**Experiment to Test Hypothesis**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Falling Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1</td>
<td>140</td>
</tr>
<tr>
<td>June 2</td>
<td>257</td>
</tr>
<tr>
<td>June 3</td>
<td>357</td>
</tr>
<tr>
<td>Buraset 1</td>
<td>102</td>
</tr>
<tr>
<td>Buraset 2</td>
<td>287</td>
</tr>
<tr>
<td>Sustate 1</td>
<td>127</td>
</tr>
<tr>
<td>Sustate 2</td>
<td>327</td>
</tr>
<tr>
<td>Hartog 1</td>
<td>90</td>
</tr>
<tr>
<td>Hartog 2</td>
<td>190</td>
</tr>
<tr>
<td>Hartog 3</td>
<td>232</td>
</tr>
<tr>
<td>Hartog 4</td>
<td>340</td>
</tr>
</tbody>
</table>

Temperatures 4°C, 20°C, 33°C, 56% R.H.

 Tested for amylose (Wheatrite and Falling Number Machine) at days 6, 10, 15, 20, etc.

**Apparatus**

- Airtight container at constant temp.
- Data-logger
- Saturated glucose solution
- Grain sample

End-point samples tested for loaf score.
RVA Market and Technical Review

Bronwyn Elliott

Newport Scientific Pty Ltd

Executive Summary

Sprout damage testing of wheat commonly relies on α-amylase detection. Information is required throughout the wheat production chain from researcher and breeder to grower, receival silo, trader, exporter and processor. One technique, the Falling Number instrument, has become entrenched such that novel technologies must demonstrate their correlation to it before anything else. The RVA Stirring Number Test, despite demonstrating technological superiority, price parity and international approval by the world’s pre-eminent cereal bodies has failed to displace the Falling Number instrument as a measure of sprout damage in wheat. Adoption of novel technology such as the RVA requires investment in more than just the technology development.
RVA Market and Technical Review

Bronwyn Elliott, Newport Scientific Pty Ltd

Market Needs
Pre-harvest sprouting of cereals results in large economic losses around the world in countries that experience wet conditions prior to harvest. α-amylase is used as an indicator of sprouted wheat because it is one of the important germinative enzymes which affects product quality.

Wheat is the grain most commonly tested for pre-harvest sprouting, but rye and barley may also be tested.

α-amylase is the most commonly tested enzyme, but a variety of cereal enzymes may be tested.

Major wheat producers where testing takes place are the EC, USA, Canada and Australia. China and India are major producers but do little testing.

Market Segmentation
The market for sprout damage testing includes anyone concerned with grain receival, (such as grain handling authorities), exporting and trading organisations, grain growers, grain processors and grain breeders and researchers.

Grain growers require a low capital cost test which is simple to use and interpret.

Grain receival sites require a low capital cost test which is reliable, repeatable and simple to use and interpret.

Grain exporting and trading organisations also require a robust method which is reliable, repeatable and simple to use and interpret. They may also be prepared to invest more for more complex information and test flexibility.

Grain processors, breeders and researchers want reliable, repeatable results combined with complex information and test flexibility.

Common to all markets is the need to derive and report data in a way which is understood and accepted by their customers.

Market Motivations
Grain growers would like to be able to test grain from individual paddocks and parts of paddocks before harvest so that damaged grain could be harvested separately from sound grain. Financial losses that result from downgrading the whole crop, and costs associated with transporting damaged grain to distant receival silos could be avoided. Having tested their crop, grain growers would also be in a stronger position to negotiate a selling price for their grain.

Grain receival sites would like to test samples quickly to prevent damaged grain being mixed in bulk with sound grain which leads to the downgrading of the grain
from the whole silo. Low capital cost would enable a greater number of sites to use the technology.

Grain exporting and trading organisations would like to test samples to determine a selling price for their grain, and to satisfy the specification requirements of buyers in the market. Results should be derived using internationally accepted methods and correlated to established test techniques.

Grain processors, breeders and researchers would like to be able to do a range of individual and innovative tests which would give them technological or market advantage, and which would enable them to respond to changing needs and environment.

**Technology Analysis**

Visual assessment is the most common method farmers and receival sites use for assessing pre-harvest sprouting in cereals. Assessment is totally subjective.

The Falling Number instrument is the most common test instrument. FN is used worldwide and approved by the pre-eminent cereal science organisations. Falling Number clone instruments are available in some countries, although they are not approved methods of the international standards organisations. The capital cost of the Falling Number instrument is prohibitive for many markets and limits the number of installations even in the sophisticated markets. It is unsuitable for use by grain growers due to its high capital cost, lack of portability, use of glassware, and need for a water supply.

Colourimetric methods, most commonly Megazyme Ceralpha and Amylazyme methods, are not widely used due to the high degree of laboratory skill required to achieve the quoted test accuracy. They are unsuitable for use by grain growers or in receival silos.

Antibody methods are easy to use, but new and not well accepted to date as results are approximate. They are suitable for use by grain growers, but so far not accurate enough for grading.

The Rapid Visco Analyser 3-minute test is internationally approved, but not widely used for assessing α-amylase due to its capital cost and market commitment to the entrenched Falling Number test. It is not suitable for use by grain growers.

The Brabender amylograph has long been the standard used by cereal chemists to measure sprout damage, but it is expensive, slow and only suitable for laboratory use.

The most sophisticated models of the Rapid Visco™ Analyser have the ability to both cook and cool the sample to produce a complete starch pasting gelatinisation (current models are RVA-StarchMaster, RVA-Super3 and RVA-4). They have gained significant market share from the Brabender amylograph, and while utilising small samples and rapid tests, are only suitable for laboratory use.

**RVA Development to Meet a Market Need**

After the disastrous harvest of 1983, the Australian Wheat Board called representatives from all sectors of the industry to a "National Forum on Weather Damage in Wheat", to seek a satisfactory means of screening grain at the receival silo for sprout damage.
Visual checking had proved inadequate and the Falling Number test was seen as unsuitable for silo use due to its high capital cost, lack of portability, use of glassware, and the need for a water supply. The time for the test was also outside the required truck turn around-time of 3 minutes in most cases.

Various alternatives such as better visual examination, near infra red reflectance analysis, a shortened Falling Number test, tests for \( \alpha \)-amylase activity with synthetic substrates or antibodies and other tests were suggested.

Any acceptable method would need to be accurate, objective, simple, inexpensive and provide results correlated to Falling Number, especially in the critical 200-350 second region, values in 3 minutes or less. It also needed to be rugged, portable, easy to use by non-technical and relatively untrained operators and able to operate without running water to be suitable for Australian silo conditions.

The Rapid Visco™ Analyser 3-minute test was developed to meet the requirements specified. It measures the same paste that the Falling Number instrument measures, but by stirring the sample in an aluminium container, producing a Stirring Number result. Both tests measure the amount of amylase enzyme which reduces the viscosity of the cooked flour and water paste when it is present in sprouted wheat.

The RVA's rotational viscosity measuring system was chosen because it is robust and flexible.

A propeller shaped paddle was chosen because it keeps the ground wheatmeal in suspension most efficiently throughout the test.

An aluminium sample canister was chosen because it allows the sample to be heated to gelatinisation temperature in less than 30 seconds in order to maximise the liquefying effect of \( \alpha \)-amylase. It can also be held at near 100°C so that it measures similar temperature effects on the starch as the Falling Number instrument. In addition it is also disposable, recyclable and reasonably inexpensive.

The pre-heated copper block which clamps around the canister was designed to provide consistent, repeatable heat transfer rates and thus sample heating rates. It also brings the sample above gelatinisation temperature very rapidly. In addition it eliminates any effect of variation in initial temperature of the mixing water.

The RVA measures viscosity by monitoring the stirring motor current as it turns the paddle in the paste producing a Stirring Number result. Viscosity at 3 minutes forms the basis of the test.

**Stirring Number Field Results**

The first prototypes used an aluminium block and a lever operated clamp mechanism and demonstrated the potential of the instrument for sprout damage testing.

Improvements including a copper heating block with assisted clamping which heated the sample faster allowed the \( \alpha \)-amylase reaction to be completed and the starch viscosity to stabilise during the test. Maximum temperature of 96°C (later 95°C) afforded precise results without boiling at the altitude of many silos. These prototypes known as the “Green Machines” provided results highly correlated with Falling Number values.
The first commercial Rapid Visco™ Analyst, model RVA-3, was produced by Newport Scientific Pty Ltd in 1986 and evaluated by the Australian Wheat Board as "reliable, with repeatability acceptable for utilization in the field".

Prime Wheat of NSW (now known as NSW Grain Corp) conducted a trial to compare Stirring Number and Falling Number methods in 1993. One RVA and one FN were used in the central laboratory and one RVA and three FNs were used in various silo receival stations.

The sample set consisted of 155 sound and damaged wheat samples representing 22 cultivars and four receival sites. Samples were ground and tested in the field, and ground and tested in Prime Wheat's Central Laboratory. Results were presented in "Comparison of Stirring Number and Falling Number Tests for Detecting Sprout Damage in Wheat During Harvest" by Bason, Sing and Booth at the 44th RACI Cereal Chemistry Division Conference, 1995.

Regression data was generated for the full data set (Table 1), and for a data set consisting of 42 samples in the critical area for grading where FN ≤ 350 (Table 2). In both cases regressions were significant at p = 0.001

<table>
<thead>
<tr>
<th>Comparison of</th>
<th>Intercept</th>
<th>Slope</th>
<th>$r^2$</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silo FN, Lab FN</td>
<td>29.5</td>
<td>0.821</td>
<td>0.817</td>
<td>35.5 sec</td>
</tr>
<tr>
<td>Silo SN, Lab SN</td>
<td>13.4</td>
<td>0.949</td>
<td>0.890</td>
<td>10.6 RVU</td>
</tr>
<tr>
<td>Silo FN, Lab FN</td>
<td>16.3</td>
<td>0.323</td>
<td>0.854</td>
<td>12.2 RVA</td>
</tr>
<tr>
<td>Lab SN, Lab FN</td>
<td>10.1</td>
<td>0.321</td>
<td>0.854</td>
<td>12.1 RVU</td>
</tr>
</tbody>
</table>

Table 2.

<table>
<thead>
<tr>
<th>Comparison of</th>
<th>Intercept</th>
<th>Slope</th>
<th>$r^2$</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silo FN, Lab FN</td>
<td>-9.9</td>
<td>1.00</td>
<td>0.800</td>
<td>39.2 sec</td>
</tr>
<tr>
<td>Silo SN, Lab SN</td>
<td>1.9</td>
<td>1.07</td>
<td>0.910</td>
<td>11.0 RVU</td>
</tr>
<tr>
<td>Silo SN, Lab FN</td>
<td>-9.3</td>
<td>0.436</td>
<td>0.869</td>
<td>13.3</td>
</tr>
<tr>
<td>Lab SN, Lab FN</td>
<td>-7.7</td>
<td>0.396</td>
<td>0.902</td>
<td>10.2 RVU</td>
</tr>
</tbody>
</table>

The $r^2$ values indicate that better repeatability was achieved with RVA than with FN, and that silo conditions did not affect RVA as much as FN. It was unexpected but significant that silo RVA was also better correlated to lab FN than silo FN was.

The more repeatable results provided by the RVA reduce but do not eliminate the possibility of incorrect grading.

Table 3.

<table>
<thead>
<tr>
<th>FN-SN Calibration</th>
<th>Intercept</th>
<th>Slope</th>
<th>$r^2$</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian wheat 1999</td>
<td>61.2</td>
<td>2.68</td>
<td>0.940</td>
<td>31.2</td>
</tr>
<tr>
<td>Australian wheat 1993</td>
<td>9.27</td>
<td>3.09</td>
<td>0.962</td>
<td>31.2</td>
</tr>
<tr>
<td>Argentinian wheat 1999</td>
<td>141.3</td>
<td>1.84</td>
<td>0.948</td>
<td>20.1</td>
</tr>
<tr>
<td>US Hard Red Wheat 1993</td>
<td>79.3</td>
<td>2.60</td>
<td>0.913</td>
<td>39.8</td>
</tr>
<tr>
<td>US Durum Wheat 1993</td>
<td>-63.0</td>
<td>3.03</td>
<td>0.975</td>
<td>14.0</td>
</tr>
</tbody>
</table>

Regression data was generated for the full data set (Table 3). The SN FN relationship is specific to species, country and year. The $r^2$ results indicate that that SN and FN are correlated well, and that the relationship is generally linear.

The latest model of the RVA dedicated to the 3-Minute test is RVA-Mini3 in which the appropriate table to convert SN to FN equivalent is burnt onto the EPROM. Results can be displayed in SN, FNE (Falling Number Equivalent) or CP units (SN x 12). Data can also be downloaded from the RVA-Mini3 via a serial port on the back of the instrument for storage or analysis.

*International Acceptance*

The RVA 3-minute test is now known world wide as the “Stirring Number Test”, and has been accepted as a standard approved method of AACC (Method 22-08), ICC (Standard No 161) and RACI (Official Method 05-05). Despite this, and its technical advantages, the RVA Stirring Number Test has not been widely adopted.

RVA models which are configured to produce a complete starch gelatinisation profile (current models are RVA-StarchMaster, RVA-Super3 and RVA-4) have gained international approval and acceptance as a replacement for the Brabender ViscoAmyloGraph. The flexibility of these RVAs has seen them applied recently to the detection of late maturity $\alpha$-amylase which cannot be detected by either the Falling Number or RVA Stirring Number Tests in Australian wheat.

*Conclusion*

Falling Number assessment of sprouting is used for wheat trading around the globe. The RVA has demonstrated technical superiority and price parity with the Falling Number instrument, and has the potential to dislodge it, but the Falling Number method is entrenched in the wheat testing and trading market.

Only when the market is educated and assisted to implement alternatives to the Falling Number instrument, can the global wheat trading market be truly open to new technologies, including the RVA.

The Sustainable Energy Development Authority (SEDA) provides a model. Money initially invested in technology development ensured the availability of energy efficient products, but no market awareness and no widespread adoption of the products. However, when SEDA implemented training programmes for local councils, retailers and others to promote their “Energy Rating Scheme”, market awareness was raised. When this awareness was supported with subsidies from 20% rebate on purchase of a simple water saving shower to 50% rebate on purchase of a solar hot water heating system, the technology uptake was widespread.
Australian wheat could gain market advantage by enabling the adoption of existing technology such as the RVA Stirring Number Test, rather than by developing yet more techniques which correlate to the Falling Number test. Superior technology is already available, but market education programmes and subsidies and assistance to implement that technology in Australia's wheat markets are not.